A New Abrasive-Free, Chemical-Mechanical-Polishing Technique for Aluminum Metallization of ULSI Devices

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A new polishing technique for the aluminum (Al) metallization is developed, referred to as an Abrasive-Free, Chemical-Mechanical-Polishing (AFP) technique, in which aqueous amine and hydrogen-peroxide (H_2O_2) solution is used as a polishing liquid. Scratch-free Al plugs embedded in SiO_2 films are obtained by the AFP with the high polishing selectivity of the Al to SiO_2.

Introduction

Since plasma-etch-back processing of aluminum (Al) is difficult, a chemical-mechanical-polishing (CMP) is recognized as a key metallization technology for the formation of the Al contact-plugs and the wiring-plugs embedded in SiO_2 film[1,2]. However, problems of the scratch formation on the Al surface and the particle-contamination, which are caused by abrasive in the polishing liquid, still remain unsolved. A RCA cleaning was useful for the abrasive removal from the SiO_2 surface, but incapable for that from the Al surface. A water washing process was insufficient for removing the abrasive particles, and more than 170 particles/cm^2 were detected after the washing. Thus, a new Al-polishing technology is needed, referred to as an Abrasive-Free, Chemical-Mechanical-Polishing (AFP) technique.

Characteristics of the AFP

Aluminum films on SiO_2 were polished with aqueous amine and aqueous H_2O_2 solutions (Fig. 1). The polished thicknesses were estimated from the changes in the sheet resistance measured. When the H_2O_2 and the amine solutions were dripped at the same time, the Al polishing rate increased very much and reached to a value capable for the practical use of about 250 A/min (Fig. 2). The Al polishing rate increased both with increasing the amine concentration (a chemical factor) and with increasing the polishing pressure (a mechanical factor), indicative of the AFP as a kind of CMPs (Fig. 3). Using the amine solution of 0.1 wt% to 2 wt% only, on the other hand, the Al film was polished slightly at a constant rate of approximately 50 A/min, which was too small to use the Al metallization practically. The Al film was not polished by the H_2O_2 solution only because of the alumina formation on the Al surface. These results suggest that, in the presence of the amine and H_2O_2 solution, the Al polishing is proceeded by the Al surface hydration (or partial oxidation) and by the mechanical rubbing of the hydrate layer(Fig. 4). Due to the absence of abrasive, the polishing rate of the SiO_2 film is negligibly smaller than that of the Al (Fig. 5).

Application

For demonstration of the AFP, the Al plugs were fabricated using a combination of the Al reflow sputtering and the AFP techniques (Fig. 6). Using the Al reflow-sputtering, holes of 0.7 μm-diameters were filled with a 1.0 μm-thick Al film (Fig. 7). Then, the Al film on the SiO_2 was selectively removed by the AFP. To minimize the chemical etching inside of the Al plug or so-called as "over-etching", a high polishing pressure condition such as greater than 0.4 kg/cm^2 was selected because of the large Al polishing rate relative to the wet etching rate (Fig. 8). After a water washing process only, the Al plugs without surface scratches and abrasive-particles were successfully obtained (Fig. 9).

Conclusion

An AFP technique was developed for the Al metallization, in which aqueous amine and hydrogen-peroxide was used as the polishing liquid. Scratch-free and abrasive- particle-free Al plugs were obtained successfully. The AFP enables us to make a high conductive Al wiring plugs embedded in SiO_2 films with a flat surface, thereby indicative of a wide practical use for the metallization of ULSI devices.

References

[1] C.Yu, et.al., IEEE 1991 VMIC Conf., Proc., p199.
[2] S.Roehl, et.al., IEEE 1992 VMIC Conf., Proc., p22.

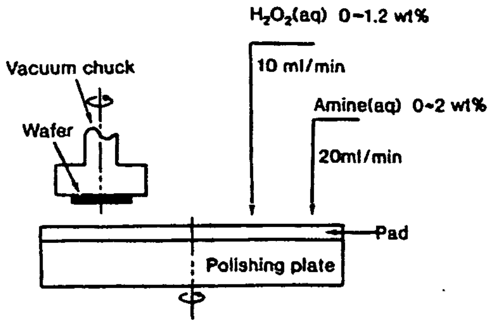

Figure 1 An illustration of a semiautomatic polishing equipment for the AFP of Al films. The polishing liquids of the amine and the H_2O_2 solutions are dripped to the polishing pad.

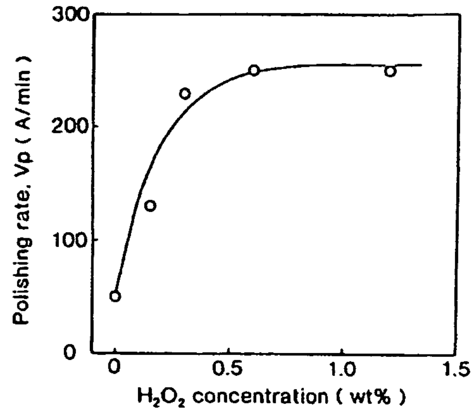

Figure 2 Effect of the H_2O_2 concentration on the Al polishing rate. The polishing pressure and the amine concentration dripped were fixed at 0.28 kg/cm² and 1.0 wt%, respectively.

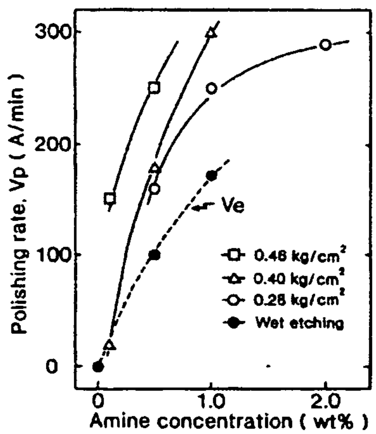

Figure 3 Effects of the amine concentration dripped and the polishing pressure on the Al polishing rate. The H_2O_2 concentration dripped was fixed at 0.6 wt%. The polishing rate is affected by the amine concentration (a chemical factor) and the polishing pressure (a mechanical factor). The polishing rates were larger than the chemical wet etching rates of the Al, (V_e). The Al film was not polished by the H_2O_2 (oxidizer) solution only.

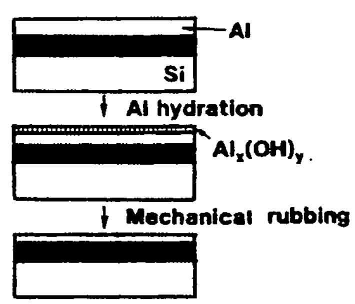

Figure 4 A mechanism of the Al polishing by the AFP. The AFP is proceeded by a kind of chemical-mechanical polishing, in which the hydration of the Al surface occurs by the reaction between Al and the polishing liquid dripped, and the surface hydrate layer is rubbed with the polishing pad.

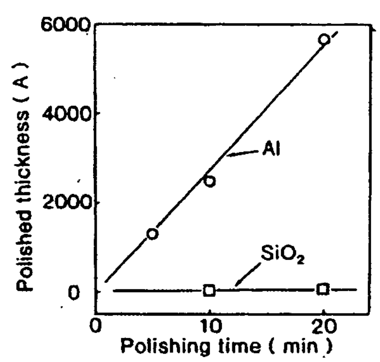

Figure 5 The polished thicknesses of the Al and SiO_2 films as a function of the polishing time duration. The polishing pressure and the concentrations of the amine and H_2O_2 solutions were 0.46 kg/cm², 0.5 wt% and 0.6 wt%, respectively. The polishing rate of the Al relative to the SiO_2 was more than 100:1.

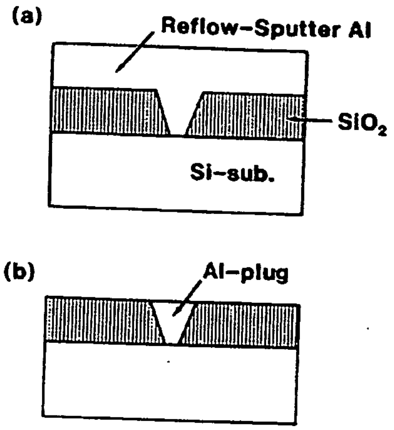

Figure 6 Process sequence of the Al plug formation by (a) an Al- reflow sputtering and (b) the AFP.

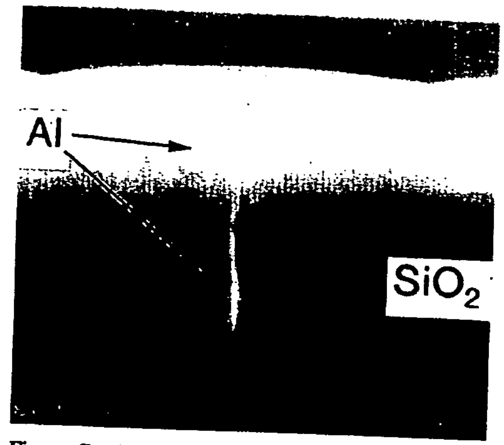

Figure 7 A cross sectional SEM micrograph of the Al film on the SiO_2 film with 0.7μm-diameter holes obtained by a Al-reflow sputtering. The substrate was heated at 470°C.

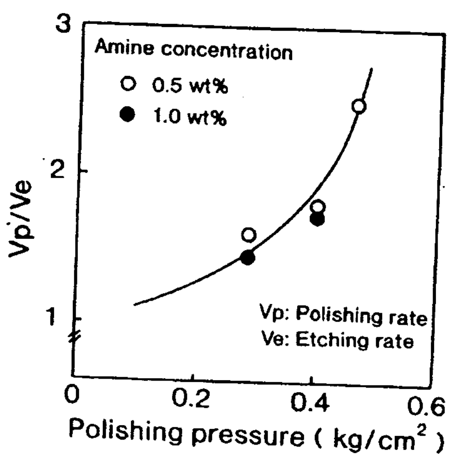

Figure 8 Effect of the polishing pressure on the Al polishing rate relative to the wet etching rate, (V_p/V_e).

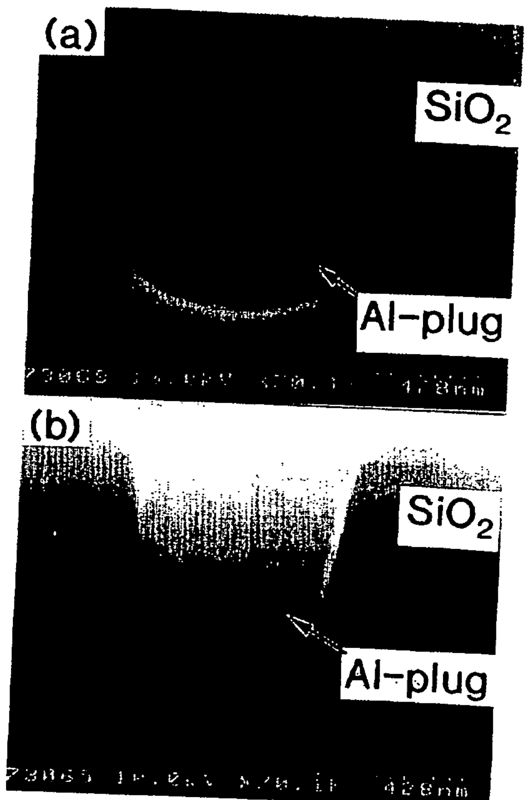

Figure 9 SEM micrographs of (a) the surface and (b) the cross-section of the Al plug obtained by the AFP technique.